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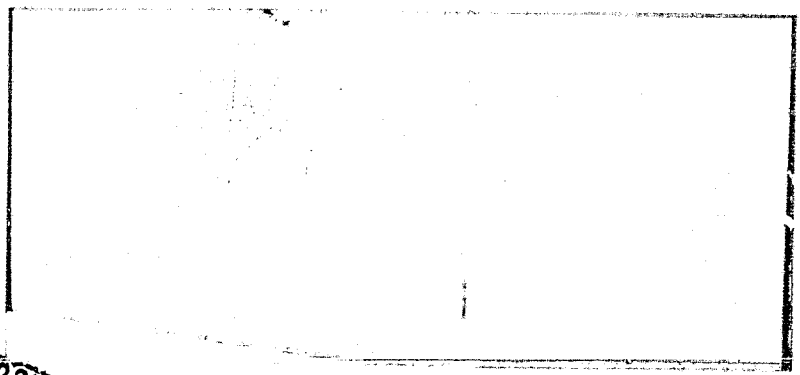

PROGRAM IN INFORMATION POLICY

ENGINEERING-ECONOMIC SYSTEMS DEPARTMENT

STANFORD UNIVERSITY • STANFORD, CALIFORNIA 94305

RESEARCH IN SPACE COMMERCIALIZATION, TECHNOLOGY TRANSFER, AND COMMUNICATIONS

Annual Report

for the Period

October 1, 1981 - September 30, 1982

NASA Contract NASW 3204

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University Stanford, California 94305

CONTENTS

Summary

This report describes activities under NASA Contract NASW 3204, a program of research and internships in technology transfer, space commercialization, and information and communications policy, for the period from October 1, 1981 to September 30, 1982. This program has two coordinated activities: the provision of internships by Ph.D. candidates in the Engineering-Economic Systems Department at NASA Headquarters, and the conduct of research by EES students and faculty at Stanford University.

During this year the project was in a phase-down mode. Three interns were working at NASA Headquarters, and three post-internship research assistants were working at Stanford. No pre-interns were supported. One of the post-internship research assistants and one of the interns have taken jobs in industry. The other two interns have returned to Stanford for the final year of post-internship support under the project.

The intern's activities are reviewed in the section on off-campus activities. On-campus research during the year involved work on following projects:

- The costs of conventional telephone technology in rural areas.
- An investigation of the lag between the start of a research and development (R&D) project and the development of new technology, using NASA patent and patent-waiver data.
- Studies of the financial impact and economic prospects of a Space Operation Center (SOC).
- A study of the accuracy of expert forecasts of uncertain quantities.
- A report on frequency coordination in the Fixed and Fixed Satellite services at 4 and 6 GHz.

These activities are summarized on the following pages.

Program Objectives

The first objective of this program is to make available to NASA, as interns, a group of Ph.D. candidates trained in the application of quantitative analytical techniques to policy issues. The second objective of the program is the conduct of a research program in national space policy, with special reference to (a) the commercialization of space and technology, (b) information and communications policy. Research resulting from the program is intended to provide both specific and long term policy perspectives to NASA. Because the project is phasing down, no pre-internship training for students has been undertaken since there will be no new interns under the program. Program staff during the year was as shown in Table 1. Two of the six students shown have taken jobs in industry. Michael Simon accepted a position with General Dynamics in a group working on the Space Operations Center and the space platform. Steven Glass accepted a position with Apple Computer.

Table 1
PROJECT STAFF

Project Staff — Stanford University

Donald A. Dunn, Professor, Co-Principal Investigator

Carson E. Agnew, Assistant Professor, Co-Principal Investigator

Steven Glass, Research Assistant

Thomas Lehmann, Research Assistant

Peter Matlock, Research Assistant

Project Staff — Washington, D.C.

David Cariño, Intern, NASA

Michael Simon,, Intern, NASA

Dean Olmstead, Intern, NASA

Review of Off-Campus Activities

Off-campus, Mr. Dean Olmstead and Mr. David Carino were assigned to the Office of Space Tracking and Data Systems (OSTDS) and the Communications Division of the Office of Space Science and Applications, respectively. The following subsections summarize their activities as interns.

Space Debris

In July 1980, research conducted at the Johnson Space Center (JSC) indicated a possible increasing hazard to space missions from orbital debris. Responsibility for the geostationary earth orbit (GEO) component of the orbital debris issue is in the OSTDS at NASA Headquarters. Dean Olmstead assumed this responsibility upon arrival at NASA and began working with JSC to develop a funded institutionalized study program.

A 10-year orbital debris study program was formulated which detailed those study elements pertinent to an improved understanding of the GEO debris problem. The program plan reflected the results of the Orbital Debris Workshop held at JSC in July 1982 which Mr. Olmstead helped develop and at which he presented a paper on the relationship of physical and radio frequency crowding within an international context. He also negotiated and submitted funding requirements for FY83 support.

The GEO debris program is now assigned to the NASA Headquarters Frequency Manager and work is continuing on the final steps of implementing the institutional structure necessary for continuity and coordination.

Also, Mr. Olmstead worked with the Department of State and NASA's International Affairs Office on an orbital debris initiative for the United Nation's UNISPACE' 82 Conference. He presented a briefing paper on the

issue to the Department of State's Interagency Preparatory committee for the International Telecommunication Union (ITU) Plenipoteniary Conference. In response to the FCC Docket on 2° spacing of GEO communications satellites, he submitted a paper addressing the impact of reduced spacing on the probability of collision. Besides traveling to JSC for the workshop, Mr. Olmstead also visited the Air Force Space Control Facility in Sunnyvale, CA, to initiate an exchange of information with JSC.

NASA-wide Long-Range Telecommunication Network Planning Study

OSTDS has the responsibility of managing all communications within NASA. Within OSTDS, the Director of the Communications and Data Systems Division has recognized that changes in the telecommunications environment require a more long-range strategic planning.

Dean Olmstead assisted the Director in defining and implementing this effort which currently consists of two components: a regulatory legislative study and a NASA communications system architecture study. For the regulatory/legislative investigation the services of Dr. Alan Pearce, a Washington consultant, were procured to assist Dean in obtaining interviews with telecommunications policy makers. An Interim Report was submited in April 1982 and the Final Report is in preparation. For the network architecture component, Mr. Olmstead finalized the Statement of Work and other supporting documents necessary to initiate a procurement. When responses were received from industry, he served on the technical review committee. The committee's final report was in preparation when he left Washington.

ITU Final Meetings

Mr. Olmstead attended the ITU Final Meetings in Geneva, Switzerland for four weeks in October 1981 as a member of the U.S. Study Group 2 (Space Research and Radio Astronomy) Delegation. He participated in the work of Study Groups 2 and 4 contributing where possible and gaining insights to the operations of an international bureaucracy.

Orbit-Spectrum Allocation

The existing method of allocating the orbit-spectrum resource is not satisfactory to many countries and several ITU Conferences have been planned in the next five years to define and implement a more popular methodology. Mr. Olmstead contributed to the U.S. efforts to prepare for these conferences through several activities. He developed a briefing, which addressed the implications of consideration of this issue at UNISPACE'82 on future ITU Conferences, for NASA Administrator James Beggs, head of the U.S. Delegation to UNISPACE'82.

ITU Plenipotentiary/Conference

For the ITU Plenipotentiary Conference, Mr. Olmstead developed U.S. position papers on a regional presence for the ITU and the relationship between physical and radio frequency crowding. As a major U.S. initiative for this conference, an international telecommunications training institute is being developed. Mr. Olmstead served as NASA's representative on a four person curriculum committee and he began an investigation of possibilities for a NASA contribution of facilities for the Institute. A briefing was given to NASA Administrator James Beggs on this. Dean continues to participate in an effort to find a suitable NASA contribution.

Commercial Assessment of a Land Mobile Satellite

David Carino participated in meetings among NASA personnel and contractors in which commercial viability of a land mobile satellite system (LMSS) was discussed. He critically reviewed and commented on several reports assessing market size and financial viability of an LMSS. He also reviewed drafts of papers prepared as potential annexes to FCC filings in the Cellular Land Mobile area. The intent of these filings was to persuade the Commission to allocate frequencies for cellular systems in a manner which would be compatible with the LMSS concept.

Appraisal of Communication for Developing Countries

In the area of satellite communications for developing countries, Mr. Carino undertook the following activities:

- He reviewed and commented on the interim and final reports on Pacific Basic Communications by the Public Service Satellite Consortium (PSSC).
- He reviewed and commented on a proposal to utilize transponders on NASA's Tracking and Data Relay Satellite for communications links among the Pacific Islands.
- He attended the Pacific Telecommunications Conference '82 in Honolulu, Hawaii, June, 1982.
- He analyzed an ITU report on rurual telcommunications for Africa.
- He gathered data on population distribution in Pacific Islands, as a prelude to forecasting communication demand.

Review of On-Campus Activities

The following subsections contain discussions of research conducted in the on-campus program.

The Cost of Local Rural Telephone Service (Agnew)

This project was a study of investment costs of serving a rural telephone subscriber in the United States. In particular, a simple cost function for the investment cost per additional rural telephone subscriber was estimated, and a comparison was made between cost estimates obtained from this function and a number of engineering studies.

This research was undertaken because, although a number of advanced technologies exist for providing rural service, no such technologies have been implemented in the U.S. except experimentally. This may be because, at present, the local telephone company is the principal provider of telecommunications services to rural areas. Service is heavily subsidized by the Rural Electrification Administration (REA) through loans and loan guarantees with interest rates as low as 2% per year. Also, the telephone separations and settlements process appears to have caused long distance and urban services to subsidize local rural telephone service, especially residential services.

Such subsidization of rural service may have suppressed innovation in rural telephony by keeping the apparent cost of service below its true cost. New technologies, such as NASA's proposed rural mobile communication service, may in fact have a lower true cost than the existing service. However, if the cost of the new technologies is above the subsidized cost, innovation is unlikely to occur.

Our analysis (in Report No. 35, "The Initial Cost of Local Rural Telephone Service") shows several things about rural equipment costs. Perhaps the most significant is that our cost estimates, as well as the majority of the engineering studies surveyed, indicate that adding a rural subscriber cost about $500 in 1972 dollars. (This figure includes the cost of equipment on subscribers' premises, a local loop and an incremental cost of local switching. It does not include any additional costs associated with the subscriber's use of the long distance network.)

The value of $500 per subscriber is much less than the conventional estimate of about $1,000 per main station often cited by the industry. It is also less than the average increase in book value for REA borrowers, $940 in 1972 dollars. For reasons noted in the report, however, all the cost estimates reported may understate the social cost of rural telephone service. If deregulation eliminates the present distortions and subsidies, the capital costs for rural companies will rise and our estimates will be too low. Hence, any new technology whose costs compare favorably to existing service using the estimates presented here will be even more attractive in a deregulated environment.

The Lag Between R&D and the Development of a New Technology (Glass)

This study was concerned with the lag which occurs between the start of a NASA-sponsored research project and the development of new technology based on that research. This study was originally part of a larger study initiated by Mr. Glass during his time as a NASA intern. The original study involved information from the applications for patent waivers on file at NASA Headquarters. Unfortunately, some of this data was lost by the computer subcontractor at NASA and could not be recovered. Consequently, the

work contained in Report No. 40 ("An Investigation of the Lag Between the Start of Research and the Development of a New Technology") was prepared using aggregate rather than detailed statistics.

In that report, the time lag was measured by maximizing the correlation between a lagged time series for R&D effort and a time series for reports of technology development. R&D effort was measured in two ways: by NASA R&D spending and NASA employment. The timing of technology development was measured in three ways: by invention disclosures (either contractor or NASA employee disclosures) and by patent applications reported to NASA. In three of the six cases a significant lag was found with a duration of one year, in a fourth case the lag was zero years. In the other two cases there was no significant relationship.

This lag of one to zero years is shorter than other values found in literature. A possible explanation for this discrepancy is that research on government R&D projects commences before the indicators of research efforts show a change.

Financial Assessments and the Prospects for the Space Operations Center (Simon)

During Michael Simon's pre-internship year at Stanford he initiated work on the financial prospects for the space operations center (SOC). He was encouraged to continue this during his internship, and produced two reports. The first of these ("Financial Assessment of the Space Operation Center as a Private Business Venture," Report No. 39) was presented to the American Astronautical Society at the 1981 meeting in San Diego. It presented a hypothetical revenue model for SOC services and compared revenues

with NASA estimates of SOC development and operating costs. Based on a 1985-2000 investment period, a present value analysis shows a potential for a substantial profit in a private SOC venture, along with the possibility of large losses. (Present value estimates range from 8.6 billion dollars to -3.3 billion.)

The second report ("Private Financing and Operation of a Space Station: Investment Requirements, Risk, Government Support, and Other Primary Business and Management Considerations," Report No. 43) discusses the financial aspect of space station operations as the private sector might view them. This report outlines the significant problems which a private company would face if it were involved in a space station enterprise, and suggests possible government roles in helping to overcome them. This analysis is relevant to NASA's interest in including the private sector in the commercialization of a manned presence in space.

Accuracy of Expert Forecasts (Agnew, Matlock)

Expert predictions of future events are a fundamental requirement in policy making. For instance, the NASA Communications Program relied on forecasts of the demand for orbit-spectrum as partial justification for its 20-30 GHz research program. Research is being conducted at Stanford on a number of aspects of the reliability of experts.

During this year, research dealt with multiple assessments by multiple of experts. At present, such assessments may be gathered informally, semi-formally (e.g., the "Delphi method") or using formal (e.g., Bayes) methods. We consider a formal procedure for evaluating a vector of uncertain quantities by asking a panel of experts a number of questions, some with answers

known to the decision maker and some not. Such multiple assessments provide a cross-check the experts' reliability--this is sometimes called "calibration."

The work on expert assessment led to the development of a procedure for calibrating certain expert assessments (Report No. 36, "Multiple Probability Assessments by Dependent Experts.") To implement this procedure, data has been gathered on the forecasts of economic quantities by panels of experts. At the time of this report the data has been coded for computer processing, and given a preliminary cleaning. A computer program has been written implementing the method described in Report No. 36. It is anticipated that final cleaning of the data, and analysis of it using the Baysian conjugate prior method will take place during the coming year.

Market-oriented techniques for spectrum use (Agnew, Dunn)

The efficient allocation of satellite orbit spectrum is of continuing concern under this program. During this period a paper (Report No. 44, "Frequency Coordination and Spectrum Economics") was prepared on the use of frequency coordination in the microwave bands 4-6 GHz, for the Fixed (terrestrial) service and the Fixed-satellite service. (The so-called "C-band".) Although many people believe that market techniques for allocating the spectrum are technically unworkable, frequency coordination has many aspects of a market. In particular, the rules of frequency coordination provide implicit, property rights in spectrum to existing users. Other provisions of the rules for frequency coordination allow trading of these rights to take place. The frequency coordination "market" can be shown to promote economic as well as technical efficiency. The paper suggests that the ideas behind coordination be expanded to other radio services.

Appendix 1: Cumulative List of Program Participants

Faculty

Donald A. Dunn, Professor

Carson E. Agnew, Assistant Professor

John T. McAlister, Adjunct Professor

D. Warner North, Consulting Professor

Edward G. Cazalet, Consulting Professor

Students*

Murray R. Metcalfe

Frederick E. Dopfel

Ralph D. Samuelson

J. Lindsay Bower

Richard Chee, Jr. (Senate Committee on Commerce, Science and Transportation)

Mark J. Matousek (Senate Committee on Commerce, Science and Transportation)

Matthew R. Willard (NASA Headquarters)

Robert D. Stibolt (NASA Headquarters)

Franklin G. Neubaur (NASA Headquarters)

Steven Glass (NASA Headquarters)

Peter Matlock (NASA Headquarters)

Thomas Lehmann (NASA Headquarters)

David Cariño (NASA Headquarters)

Michael Simon (NASA Headquarters)

Dean Olmstead (NASA Headquarters)

* Internship shown in parentheses.

Appendix 2: Cumulative List of Reports and Working Papers

1. R. D. Samuelson, "An inquiry into the household economy," Report No. 22, Program in Information Policy, October 1979.

2. D. A. Dunn, "The economic basis for national science and technology policy," Report No. 23, Program in Information Policy, October 1979.

3. M. R. Metcalfe, E. G. Cazalet, and D. W. North, "An illustrative analysis of technological alternatives for satellite communications," Report No. 24, Program in Information Policy, October 1979.

4. R. D. Stibolt, "Economic aspects of spectrum management," Report No. 25, Program in Information Policy, October 1979.

5. F. E. Dopfel, "Cost comparison of competing local distribution systems for communication satellite traffic," Report No. 26, Program in Information Policy, October 1979.

6. M. Matousek, "Government patent policy: an analysis of the effects of three alternative patent policies on technology transfer and the commercialization of government inventions," Report No. 27, Program in Information Policy, October 1979.

7. H. Lapple, "Improving NASA's technology transfer process through increased screening and evaluation in the information dissemination program," Report No. 28, Program in Information Policy, October 1979.

8. M. Willard, "Understanding the market for landsat data and products in developing countries," Report No. 30, Program in Information Policy, September, 1980.

9. C. Agnew, "Alternative licensing arrangements and spectrum economics: the case of multipoint distribution service," Report No. 31, Program in Information Policy, January 1981.

10. M. Matousek, "COSMIC and the market for commercial software," Report No. 32, Program in Information Policy, April 1981.

11. P. Matlock, "A survey of machine readable data bases," Report No. 34, Program in Information Policy, August 1981

12. C. Agnew, "The initial cost of local rural telephone service," Report No. 35, Program in Information Policy, October 1981.

13. C. Agnew, "Multiple probability assessments by dependent experts," Report No. 36, Program in Information Policy, November 1981.

14. M. Simon, "Financial assessment of the space operations center as a private business venture," Report No. 39, Program in Information Policy, January 1982.

15. S. Glass, "An investigation of the lag between the start of research and the development of new technology," Report No. 40, Program in Information Policy, February 1982.

16. M. Simon, "Private financing and operation of a space station: investment requirements, risk, government support, and other primary business and management considerations," Report No. 43, Program in Information Policy, September 1982.

17. C. Agnew and R. Gould, "Frequency coordination and spectrum economics," Report No. 44, Program in Information Policy, September 1982.

Working Papers

1. M. Willard, "Landsat: Historical Overview and Political Analysis," August 1981.

2. M. Metcalfe, "Evaluating the Benefits of Public Sector R&D Projects: Accounting for Technology Transfer," May 7, 1979 (Revised July 1979).

3. D. Dunn, "Organizational Options for the Transfer of Space Technology to Commercial Makets," February 1979.

4. L. Bower, "Legal Restraints Confronting Domestic U.S. Firms in Their Foreign Operations," February 1979.

5. R. Stibolt, "Economic Aspects of Orbit-Spectrum Allocation," February 1979.